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MAXIMUM WATER RESERVES IN THE SNOW COVER IN THE EUROPEAN TERRITORY OF THE USSR ACCORDING TO DATA FOR 1892-1960

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Translation of "Maksimal'nye zapasy vody v snezhnom pokrove na Yevropeyskoy territorii SSSR po dannym za 1892-1960 gg.", Trudy Psi., No. 148, 1966, pp. 150-160

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16. Abstract

Examined in this article is the snow cover of the European territory of the USSR, and maps of the average greatest and least magnitudes of the maximum water reserves in them are given, as well as a map of the coefficient of variation of the maximum reserve.

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MAXIMUM WATER RESERVES IN THE SNOW COVER IN THE EUROPEAN TERRITORY OF THE USSR ACCORDING TO DATA FOR 1892-1960

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Examined in the article is the snow cover of the European territory of the USSR, and maps of the average greatest and least magnitudes of the maximum water reserves in them are given, as well as a map of the coefficient of variation of the maximum reserve. /150*

The water reserve in the snow cover prior to the beginning of melting determines the magnitude of the run-off for spring flooding to a considerable extent. For the majority of rivers, the spring run-off is more than half of the annual run-off.

As has already been established in hydrology, the greatest magnitude of the water reserves in the snow cover for the winter is adopted as the maximum water reserves in the snow cover for each station per year. As is common knowledge, it usually occurs slightly earlier than the beginning of the spring melting of the snow.

First, it is necessary to dwell on the procedure for snow-measuring observations and the materials utilized for constructing the annual maps of the maximum water reserves in the snow cover. These maps were the basis of the compilation of the snow cover maps given below.

During the period from 1892-1960, the procedure for snow-measuring observations changed. From 1892-1935, the stations carried out measurements of the height of the snow cover only using rigidly-reinforced snow-measuring rods, usually 1-3 rods per station. The density of the snow close to the rods was initially determined starting in 1904. Since the winter of 1935-1936, and since the winter of 1944-1945 in the Baltic Region, snow-measuring mapping was begun

*Numbers in the margin indicate pagination in the foreign text.

at the stations. The procedure of these mappings briefly amounts to the following.

In the open terrain, which is typical for the environs of the station, a snow-measuring route in the form of an equilateral triangle with a perimeter of 1 km is laid out. The measurements of the height of the snow cover on this route is carried out every 10 m, and the measurements of the density — every 100 m. Prior to 1940, according to the instructions in effect at that time, various lengths of the mapping route were permitted — from 400 m to 2 km, and, in this case, the route could be open (at a number of stations, it was a single straight line). It is necessary to note that, until now, only the height of the snow cover was measured during the mapping at some stations. In 1959, the number of such stations was 15% of the total number of stations carrying out snow-measuring mapping; in 1937-1940, it had reached 60%.

The route of the snow-measuring mapping is fixed on the terrain, and, according to the Manual for Hydrometeorological Stations, may be changed only in that case when, as a result of some causes, it proved unrepresentative. In the majority of the stations, the route /151 passes along level terrain and gentle slopes, occupied by plowed land or meadows. Even in regions of severe erosion ruggedness, there are very few snow-measuring routes, which would intersect a ravine or a gully.

The snow-measuring mappings were carried out along the triangular route on the 10th, 20th and 30th (31st) of each month. In the most recent years, the mappings have been carried out once every five days (5th, 10th, 15th, and so on, of each month) at the end of winter, and with an unstable snow cover.

During 1892-1960, the number of stations, which carry out snow-measuring observations on the European territory of the USSR, increased strongly. However, prior to 1936, it remained generally small, varying from roughly 100-120 to 350 by years.

The following annual maps of the maximum water reserves in the snow cover formed the basis of the maps given below:

1. "Atlasa maksimal'nykh snegozapasov Yevropeyskoy chasti SSSR" [Atlas of Maximum Snow Reserves of the European Part of the USSR] [2] for 1904-1935.

2. The atlas "Karty snezhnogo pokrova Yevropeyskoy territorii SSSR za period s 1936 po 1960 gg." [Maps of the Snow Cover of the European Territory of the USSR for the Period from 1936 to 1960], compiled by the Central Institute of Forecasting.

What is more, the maps of the maximum height of the snow cover for 1892-1903 were also utilized [2]. These maps, and the maps of the average density of the snow on the date of its maximum height, were the initial maps for constructing the annual maps of the water reserves in the snow cover for 1892-1903. These reserves were taken as the maximum reserves.

The maps of the maximum water reserve in the snow cover for 1936-1960 were considerably more accurate than the similar maps for 1904-1935, and even more so than those for 1892-1903. This is associated with the fact that the maps for 1936-1960 were compiled according to the data of a large number of snow-measuring mappings (Table 1). We would note that, for 1942-1944, as a result of the conditions of wartime, there were no mappings for the western, and partially the southern, regions, and snow-measuring mappings were begun in the Baltic Region in 1945.

Table 1
Number of snow-measuring mappings utilized for compiling maps

Years	1937	1940	1947	1952	1959
Number of mappings	650	700	1400	2600	2750

During the period of the maximum accumulation of snow for the winter, detailed snow-measuring mappings were carried out at a number of stations, including run-off stations, and in the basins of some small rivers, according to the data of which one may calculate the

average magnitude of the water reserves in the snow cover with a high level of accuracy. Comparison of these magnitudes with the corresponding magnitudes determined according to the maps showed that the maps for 1936-1960 are sufficiently accurate, on the whole. One may assume that, for the basins several thousand km^2 in area, the root-mean-square error in the magnitudes of the water reserves in the snow cover, determined according to these maps (the isolines of the water reserves are plotted every 20 mm on the maps), is usually equal to 8-12 mm.

It should be noted that, during the compilation of the maps for 1936-1960, snow-measuring mappings for the extreme southern and western regions were not utilized for those years when the snow cover was unstable there. The snow cover was assumed to be stable when the snow lay for a month and more continuously, or with breaks which did not exceed three days per month.

The accuracy of the maps for 1904-1935, and especiialy for /152
1892-1903, is low. This is associated both with the substantial shortcomings of the procedure of snow-measuring observations in these years, and with the small number of stations where the observations were carried out. Thus, in 1904-1908, the density of the snow near the snow-measuring rods was determined at only 35 stations. As was already noted, in 1892-1903, the snow-measuring observations at the station amounted to readings of the height of the snow cover according to one-three rods. The maps for 1892-1935 are the least accurate for the Kola Peninsula, the northeast (Pechora Basin), and the territory of the Ukraine.

For compiling the maps of the average, greatest and least magnitudes of the maximum water reserves in the snow cover, it seems advisable to utilize all of the maps for 1892-1903, 1903-1935 and 1936-1960. One may assume that, in the given case, lengthening of the series, at the expense of the years with reduced accuracy and insufficient completeness of snow-measuring observations, increases the accuracy of determination of the average and extreme values even more, and also the coefficient of variation of

the maximum water reserves in the snow cover. On the other hand, bearing in mind the considerably greater accuracy and completeness of the data for 1936-1960, it was necessary to examine the maps of the snow cover for this period individually.

The maps of the average, greatest and least maximum water reserves in the snow cover were compiled, as was already mentioned, on the basis of the annual maps of the maximum water reserves. For this purpose, the magnitudes of the water reserves were determined, according to these maps (by years), for a sufficiently large number of geographical points, located throughout the territory generally uniformly. Then, for each of these points, the average magnitude and coefficient of variation of the maximum water reserves in the snow cover were calculated; at the same time, the greatest and least magnitudes were selected.

In view of the small number of stations, carrying out observations prior to 1935, a rather simple configuration of the isolines of the water reserves in the snow cover is characteristic for the maps for 1892-1935. It is quite clear that the maps for this period reflect only the basic information in the annual distribution of the snow cover on the European territory of the USSR. In this connection, it was also advisable to utilize a small number of geographical points for constructing the maps given below for 1892-1960; a total of 135 points were taken.

The maps for 1936-1960 are characterized by a complex configuration of the isolines. Therefore, for construction of the map of the average maximum water reserves in the snow cover according to them, it was necessary to take a considerable number of geographical points; a total of 650 points were taken. The causes, which evoke the substantial differences and bring about the complex configuration of the isolines on the maps, are examined somewhat lower.

The map, given in Figure 1, gives the average maximum water reserves in the snow cover for 1892-1960 (for the Baltic Region — for 1892-1915, 1945-1960). We see on the map that this magnitude

increases from the southwest and south to the northeast from 20-30 mm to 160-180 mm. Judging from this map, only the Privolzhskaya, Valdayskaya and Volyno-Podol'skaya Heights, and also Sevornye Uvaly, are characterized by an increased accumulation of snow. In the Urals, the water reserves in the snow is, naturally, considerably higher than in the lowlands contiguous to them.

For the period from 1892-1960, the greatest magnitude of the maximum water reserves in the snow cover (Fig. 2) was greater than 150 mm throughout the territory, located to the north of the Vinnitsa, /153
Khar'kov, Kamyshin, Aktyubinsk line, and greater than 200 mm to the north of the Gomel', Saratov, Orenburg line.

The least maximum water reserves in the snow cover for 1892-1960 are given in the form of the map given in Figure 3. As we see, this magnitude increases from the southwest to the northeast from 10 mm to 70-90 mm in the lowlands, and to 110-120 mm in the Urals at a latitude of 60-64°.

In the heaviest snow years, the effect of heights on the amount of solid precipitation is manifested more distinctly than on the average for all of these years (Figs. 1 and 2).

Making use of the maps, presented in Figures 2 and 3, one may /154
calculate the amplitude of the variations in the maximum water reserves in the snow cover for each basin (but not for very large ones) for the period from 1892-1960, i.e. for 69 years.

According to the data for 1892-1960, the coefficient of variation of the maximum water reserves in the snow cover decreases from the southwest to the northeast from 0.65-0.70 to 0.22-0.23 (Fig. 4). Consequently, there is an inverse dependence between the average magnitude and the coefficient of variation of the maximum water reserves. It is quite possible that it will be quite approximate. In passing, we would note that the coefficient of variation of the spring run-off depends not only on the coefficient of variation of /155
the maximum water reserves in the snow cover.

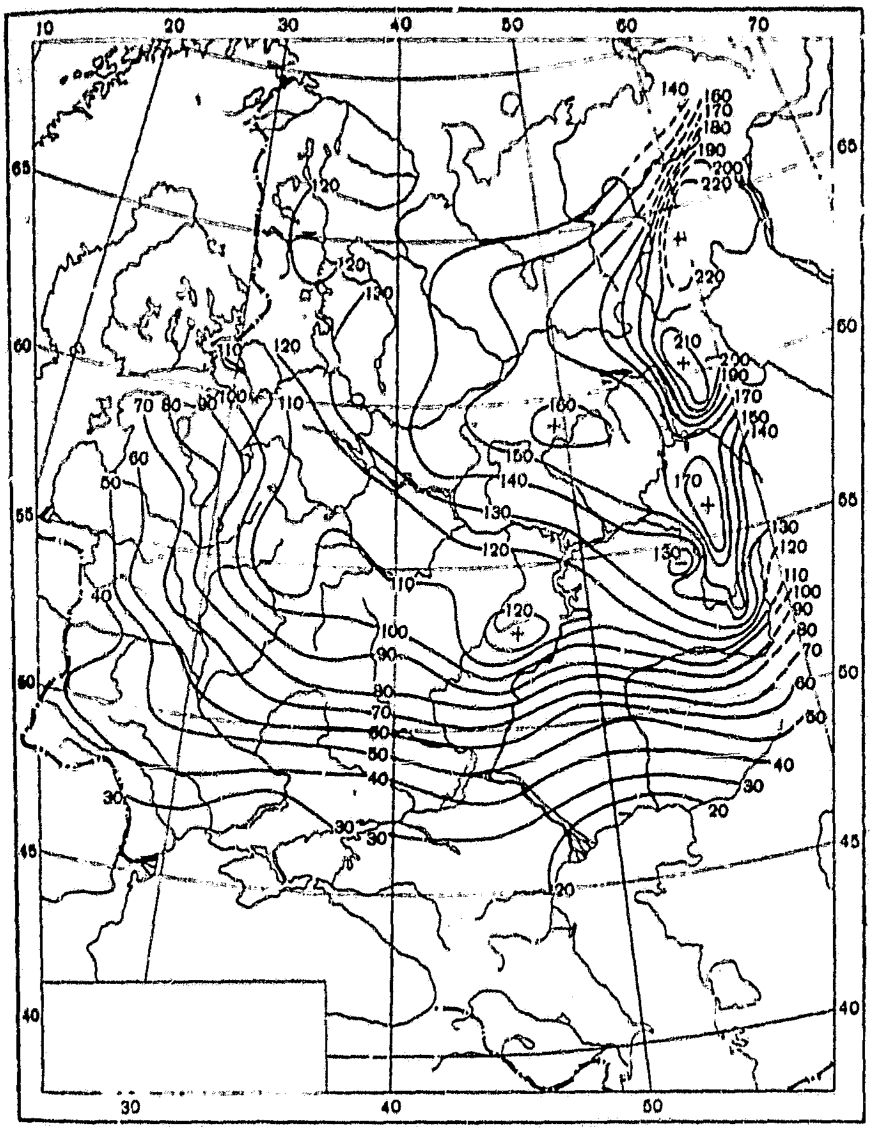

Fig. 1. Average maximum water reserves in the snow cover, according to data for 1892-1960.

By making use of the maps presented in Figures 1 and 4, one may calculate the maximum water reserves in the snow cover of a different, including a small, coverage. These magnitudes are of interest for hydrological calculations. The coefficient of asymmetry should be taken as equal to twice the value of the coefficient of variation [7].

According to the configuration of the isolines, the map of the average magnitude of the maximum water reserves in the snow cover for 1936-1960 (Fig. 5) differs considerably from the similar map compiled

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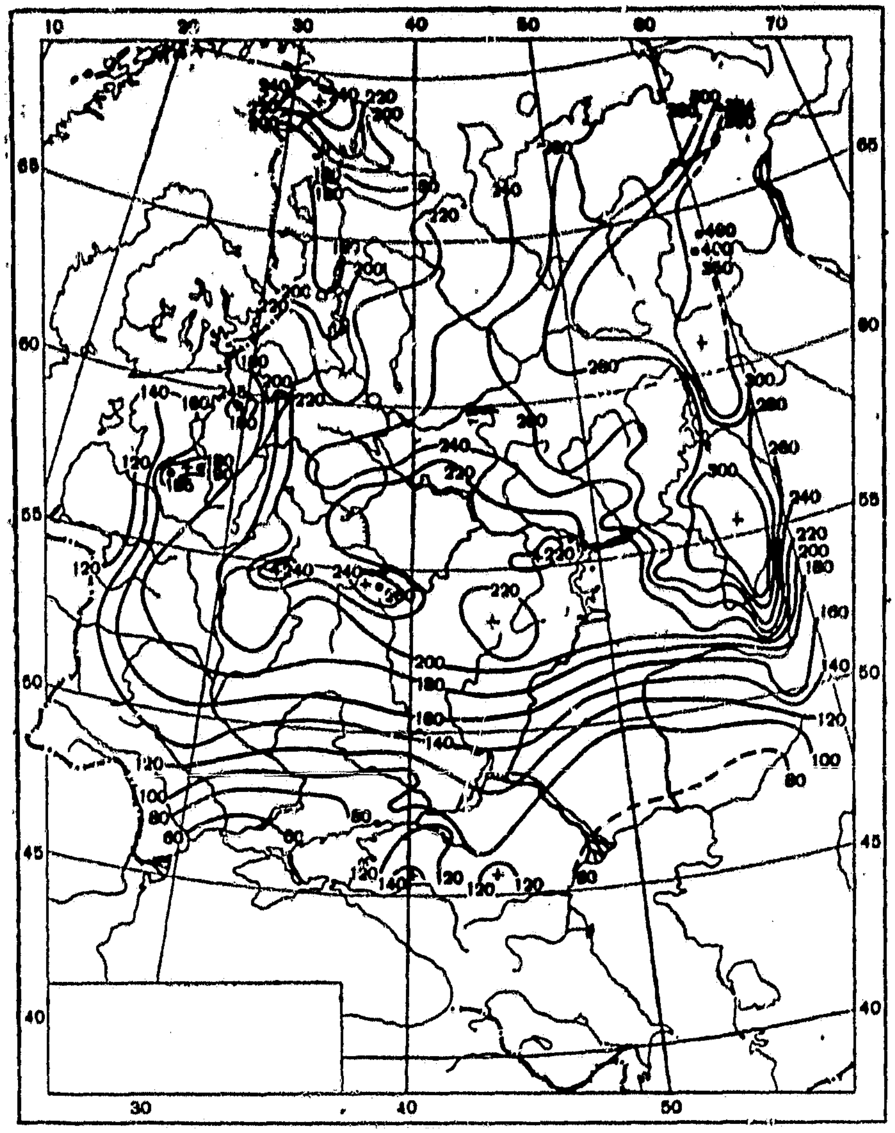

Fig. 2. Greatest of maximum water reserves in the snow cover, according to data for 1892-1960.

according to data for 1892-1960 (Fig. 1). As was noted, the snow-measuring observations in 1936-1960 were more accurate, and the major ones were carried out at an incomparably larger number of stations than in 1892-1935. This is also the main reason for the different complexity of the configuration of the isolines on both maps. /156

On the map given in Figure 5, it is evident that, in the majority of the years, the relief has a substantial effect on the distribution of the winter precipitation throughout the territory. An increased

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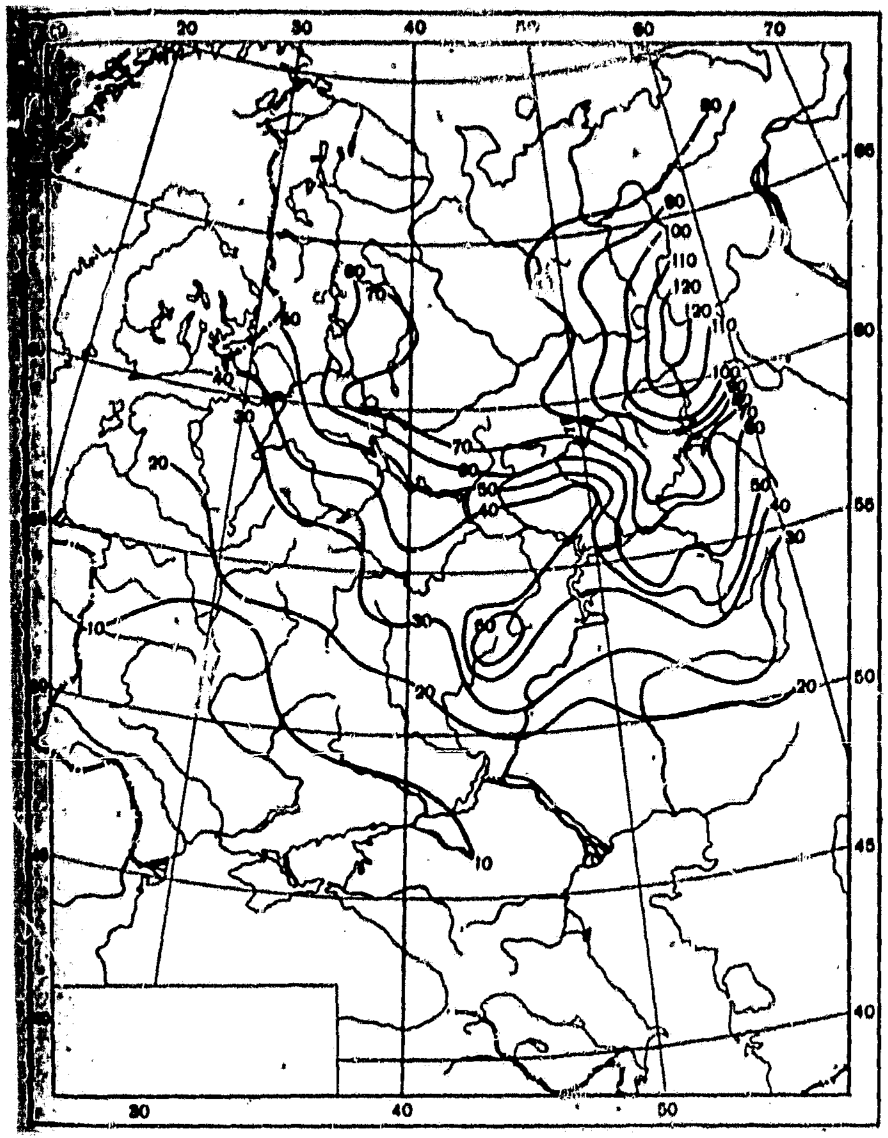

Fig. 3. Least of maximum water reserves in the snow cover, according to data for 1892-1960.

accumulation of snow is characteristic not only for large heights, as followed from the less-detailed map for 1892-1960 (Fig. 1), but also for small heights of the Baltic Region, the Minsk and Smolensk-Mosow chains, and so on (Fig. 5). This question, which is quite important for the study and understanding of the distribution of spring, and even annual, run-off throughout the territory, is covered in more detail below, on the basis of the examination of the annual maps for 1936-1960.

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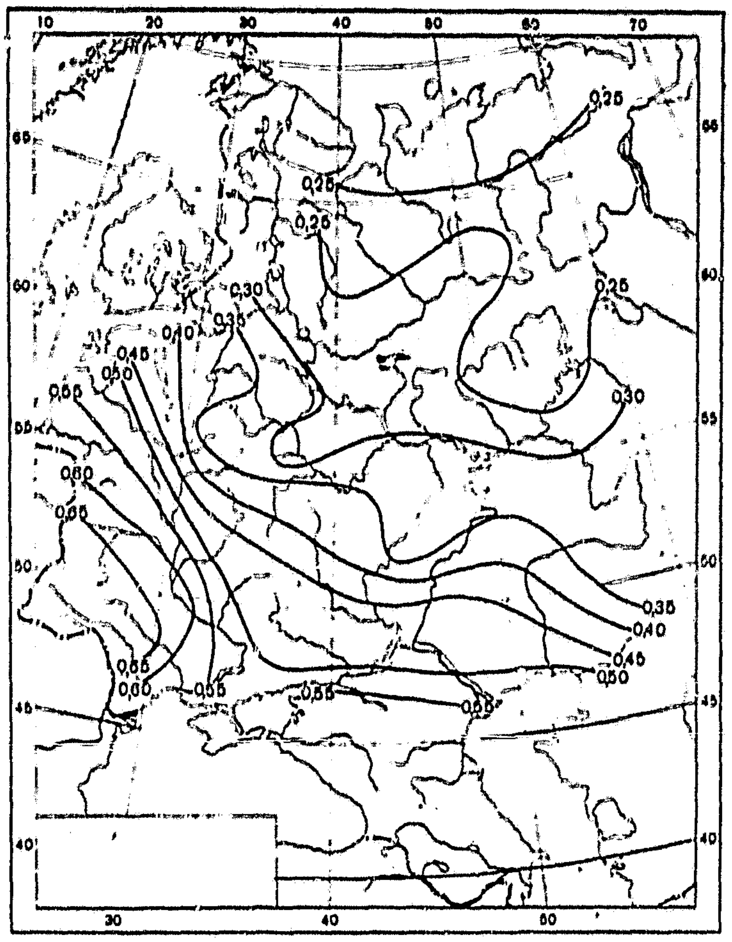

Fig. 4. Coefficient of variation of maximum water reserves in the snow cover, according to data for 1892-1960.

As is common knowledge, a considerable decrease in the level of the Caspian Sea has been observed since 1929. The main cause of this is the decrease in the annual run-off of rivers, falling to the sea, and specifically the run-off of the Volga. Insofar as the spring /157 run-off is greater than half of the annual run-off, it would be interesting to compare the snow cover of the European territory of the USSR for 1892-1935 and 1936-1960.

By making use of the maps presented in Figures 1 and 5, the average magnitudes of the maximum water reserves in the snow cover for 1892-1935 and 1936-1960 were calculated. It turned out that the first magnitudes are greater than the second in the extreme south and west by roughly 8-10 mm, and in the remaining territory, excluding

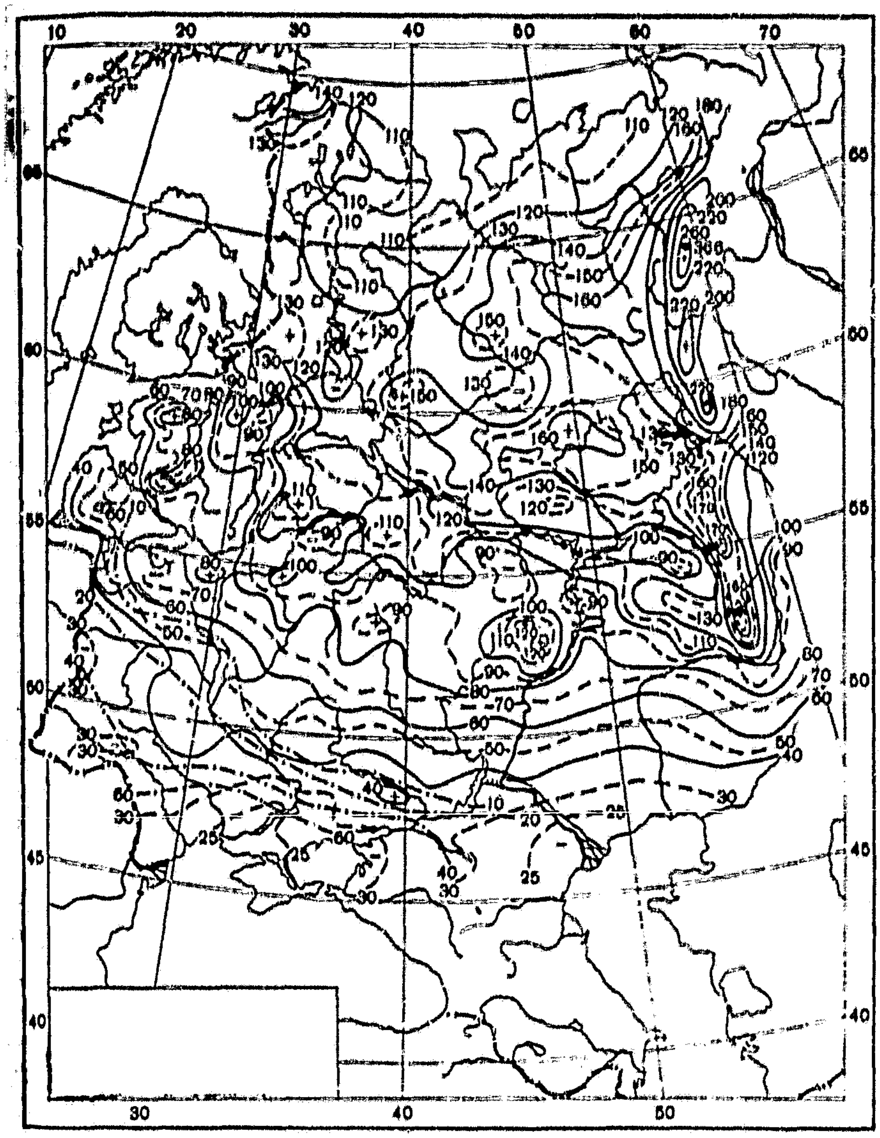

Fig. 5. Average maximum water reserves in the snow cover, according to data for 1936-1960.

part of the territory in the north, by 15-20 mm. In the Volga Basin, the difference in the examined average magnitudes is about 20 mm. We will take the coefficient of the spring run-off, according to [7], as equal to 0.6. Then, as a result of the decrease in the /158 amount of snow, the reduction in the average magnitudes of the spring run-off of the Volga for 1892-1935 and 1936-1960 will be roughly 17-18 km^2. Actually, this decrease in the run-off was somewhat greater, since, in our calculation, the data for 1930-1935 are included in the first period, and the snow in the Volga Basin was slight in 1930 and 1933-1935. The average magnitude of the annual run-off of the Volga for 1892-1935 and 1936-1960 is equal to 250 and

229 km^2, respectively.

We would note that, during the calculation of the average value and the coefficient of variation of the maximum water reserves, its magnitude, with an unstable snow cover (in 1936-1960), was taken as equal to 25 mm. This number is close to the average value of the maximum water reserves in the unstable snow cover.

We will return to the evaluation of the role of the relief in the distribution of the winter precipitation throughout the European territory of the USSR.

The fronts, which pass along the lowlands without precipitation, often provide precipitation upon approaching heights. It has been established [1,3,8] that, with flowing around of even a small height by an air current, a zone of ascent of the air masses forms in front of the height, characterized by an increased amount of precipitation, and beyond the height — a zone of "orographic shadow" with a reduced amount of precipitation. In this case, the effect of the height on the air current depends substantially on its form as well, particularly on the relationship of the length of the base of the height and its elevation. Observations show that even small heights, for example the Vidzemskaya and Kurzemskaya Heights in the territory of the Latvian SSR, play an appreciable role in the distribution of precipitation throughout the area [3,4,5,8]. Finally, it is necessary to note that the zone of maximum precipitation is often shifted relative to the central part of the height toward the moisture-bearing wind.

Thus, in various years, the effect of heights on the distribution of solid precipitation over the territory is unequal, and depends on the characteristics of atmospheric circulation throughout the winter. For example, there may be large amounts of snow on the western slopes on one and the same height in one year, and in another — on the southern slopes, as a function of the prevailing direction of the moisture-bearing winds in winter.

An increase in precipitation on the heights is undoubtedly associated with the fact that increased ruggedness of the relief is characteristic for them, and, consequently, increased roughness of the underlying surface as well. What is more, the heights are usually partially covered with forests, and this increases the roughness of their surface even more [6].

Maps of the maximum water reserves in the snow cover for 1936-1960, constructed according to a very large amount of snow-measuring mapping, indicate the considerable effect of the relief on the distribution of winter precipitation in the European territory of the USSR. In this regard, maps for individual years, when the atmospheric circulation in winter probably had characteristics which lead to an increase in the effect of the relief on the precipitation fall, are especially significant. The maps also fully corroborate the conclusion, drawn above, on the unequal effect of one and the same height on the distribution of winter precipitation over the territory in different years. At the same time, it is evident on the maps that, in individual years, an increased accumulation of snow is not observed even on considerable heights; the characteristics of atmospheric circulation are, again, probably the cause of this.

From the data of the maps for 1936-1960 (Fig. 5), it follows that increased reserves in the snow cover often occur on the Konosho-Nyandomskaya Height, the Timanskiy Range, the Northern Ridges, the /159
Tikhvinsko-Andomskaya and Valdayskaya Heights, on the eastern extremity of the Klinsko-Dmitrovskaya Chain, on the Ufimskoye Plateau, and on the approaches to it in the area between the Kama and Ufa Rivers, on the Bugul'minsko-Belebeyevskaya and Privolzhskaya Heights, northeast of the Obshchiy syrt, and in the Mugodzharskiye Mountains, with respect to the surrounding territory. The spaces between the Northern Dvina and the Mezenya, the small heights in the Baltic Region and the western slopes of the Smolensko-Mosckovskaya chain are rather frequently characterized by increased accumulations of snow.

Frequently, the regions of increased water reserves in the snow

cover have quite small dimensions — 2-3 thousand km^2. In the center of these regions, the water reserves in the snow are usually 20-40 mm greater than in the surrounding territory. The water reserves in the snow cover often change severely in a very small distance, for example by 50-60 mm over a distance of 90-100 km. It is necessary to state that the noted regions of increased accumulation of snow were picked out on the maps only in those cases when their existence was corroborated by the data of at least 2-3 stations.

In the south, primarily in the territory of the Ukraine, the Moldavian SSR and the Rostov District, the distribution of snow often depends, to a considerable extent, on the intensity and duration of the thaws. Therefore, the clear-cut effect of the relief on the water reserves in the snow cover is not usually traced here. This conclusion is related particularly to the space occupied by the Sredne-Russkaya height: because of the intense thaws, there is frequently less snow on the southwest of this height, and weakening of the thaws to the east often leads to a relatively increased accumulation of snow between the Oka and the Don, in the headwaters of the Oskol and the Seym. However, in isolated years, throughout the territory of the Ukraine, the effect of the relief on the accumulation of snow is distinctly manifested; in these cases, the increased water reserves in the snow are observed on the Donetskiy Ridge, the Priazovskaya Height, and so on.

In the Urals, more snow falls than to the west and east of them. In this case, a considerable increase in the thickness of the snow cover is observed even in the western foothills. It is interesting that the maximum snow accumulation in the Urals is shifted to the west, relative to the highest of its ridges, and sometimes even falls within the Ufimskoye Plateau.

The reduced water reserves in the snow cover, as follows from the data of maps for 1936-1960, are often observed in the region of the lower flow of the Bychegda, the Yug and the Sukhona, to the east of the headwaters of the Kama (on the eastern slopes of the Vyatsko-Permyatskiye Ridge), in the Urals between the Sylva and Chusova Rivers, between the Bugul'minsko-Belebeevskaya Height and

the Ufimskoye Plateau (chiefly along the left bank of the Belaya), and in the lower flow of the Lovata and Shelona Rivers. These regions of reduced snow accumulation are located on the flat low spaces of the Eastern European lowlands, on the eastern leeward slopes of heights, and between heights.

The difference in atmospheric circulation from year to year, as well as the intensity and regions of dissemination of the thaws, leads, as has already been noted, to a rather complex and unequal picture of the distribution of snow in the European territory of the USSR. This distribution becomes even more complex when a considerable difference is observed, at great distances, in the periods of formation of a stable snow cover, or when the snow cover lies for a short time.

In conclusion, we would note that the described characteristics of the annual distribution of snow throughout the territory indicate the necessity for having a sufficiently dense network of stations /160
carrying out snow-measuring mappings. Only with this stipulation can satisfactory accuracy of determination of the water reserves in the snow cover in the basins of rivers of small and average size be achieved.

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